Chapter 1
Stormwater Management and Planning

Contents

1.0 Overview/Purpose

The Drainage Criteria Manual (DCM) – Volume 2, Stormwater Quality Policies, Procedures and Best Management Practices is meant to provide owners, developers, engineers, and contractors with information they will need to comply with local stormwater quality requirements for drainage planning/design relating to new development/significant redevelopment and construction activities. The material in this manual is meant to assist users in determining what requirements apply and what best management practices ("BMPs") are necessary for a given site. As with any manual, it is impossible to be all-inclusive: addressing every situation. It is the owner's responsibility to ensure that the work at the site is in compliance with all applicable statutes and ordinances. This manual should be used in addition to other references and personal experience.

This manual covers the following areas:

1. Basics of stormwater quality and regulatory requirements.
2. Requirements for the development and implementation of an Erosion and Stormwater Quality Control Plan.
3. Information on the use, design and maintenance of construction BMPs that can be used to comply with the Erosion and Stormwater Quality requirements.
4. Information on construction inspection and enforcement.
5. Requirements and procedures for permanent/treatment stormwater quality BMPs in new developments/significant redevelopments.

The stormwater quality criteria and requirements of this manual are meant to be in addition to the drainage requirements and criteria listed in the Drainage Criteria Manual, Volume 1. If there are any conflicts or discrepancies between the criteria and requirements of this manual and those in the Drainage Criteria Manual, Volume 1, Engineering Criteria Manual or the City Engineering Standard Specifications, the criteria and requirements in this manual take precedence.

The BMPs included in the Drainage Criteria Manual, Volume 2 are not meant to be comprehensive. It is anticipated that as time goes on new technologies will be introduced as well as additional refinement of the current technologies. It is expected that the list of BMPs will be expanded as time goes on. Should the owner/engineer desire use of other temporary or permanent treatment BMPs, it will be necessary to submit information that supports their use and ability to adequately control stormwater quality. These requests will be reviewed on a case-by-case basis and follow procedures found in Chapters 4 and 7.

2.0 Stormwater Quality Management

Most of the public's concerns with stormwater are usually related to flooding, not water quality. People complain when their basements flood or roads become impassable and the public suffers when severe catastrophic floods cause widespread damage to property and loss of life. Very few people are aware of the water quality impacts that stormwater has on our rivers, streams, or lakes. Stormwater runoff quality can have significant impacts on the receiving waters that affect not only the aquatic ecosystem, but also the quality of our communities.

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2.1 Environmental Impacts of Runoff

Stormwater impacts streams by affecting the stream hydrology, stream morphology, water quality and aquatic ecology. The extent of impact is related to the climate, land use, and the measures implemented to address the impacts.

Briefly, the impacts on streams are:

- Stream Hydrology: Urban development affects the environment through changes in the size and frequency of storm runoff events, changes in base flows of the stream and changes in stream flow velocities during storms results in decrease in travel time for runoff. Peak discharges and volumes in a stream can increase from urbanization due to a decrease in infiltration of rainfall into the ground, loss of buffering vegetation and resultant reduced evapotranspiration. This results in more surface runoff and larger loads of various constituents found in stormwater.
- Stream Morphology: When the hydrology of the stream changes, it can result in changes to the physical characteristics of the stream. Such changes include streambed degradation, stream widening, and streambank erosion. As the stream profile degrades and the stream tries to widen to accommodate higher flows, instream bank erosion increases along with increases in sediment loads. These changes in the stream bed also result in changes to the habitat of aquatic life.
- Water Quality: Water quality is impacted through urbanization as a result of erosion during construction, changes in stream morphology, and washing off of accumulated deposits on the urban landscape. Water quality problems include turbid water, nutrient enrichment, bacterial contamination, organic matter loads, metals, salts, temperature increases and increased trash and debris.

2.2 Stormwater Runoff Constituents and Sources

Urban runoff contains many types and forms of constituents as shown in Table 1-1; some occurring in higher concentrations (see Table 1-2) than found in runoff before development and some that are not naturally present in surface runoff from undeveloped land. Runoff from undeveloped watersheds contains sediment particles, oxygen-demanding compounds, nutrients, metals, and other constituents. Once developed, constituent loads increase because surface runoff volumes increase and the sources of many of these pollutants also increase. Also, additional sources of constituents may exist in a catchment and find their way into runoff. They may include the following:

- Metals, lubricating compounds, solvents, and other constituents originating from vehicles, machinery, and industrial and commercial activities.
- Pesticides, herbicides, and fertilizers.
- Household solvents, paints, roofing materials, and other such materials.
- Pet litter, garbage, and other debris.
- Suspended solids washed off impermeable surfaces.
- Increased soil erosion during construction activities. Table 1-1 lists the common constituents in stormwater runoff and Table 1-2 lists event mean concentrations (mg/L) of constituents observed in a metro Denver study (Colorado Springs information not available).

Table 1-1. Common Urban Runoff Pollutant Sources

(Adapted form: Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. 1994. *Fundamentals of Urban Runoff Management: Technical and Intuitional Issues*. Washington, DC: Terrene Institute and EPA.)

Pollutant Category Source	Solids	Nutrients	Pathogens	Dissolved Oxygen Demands	Metals	Oils	Synthetic Organics
Soil erosion	X	X		X	X		
Cleared vegetation	X	X		X			
Fertilizers		X	X	X			
Human waste	X	X	X	X			
Animal waste	X	X	X	X			
Vehicle fuels and fluids	X			X	X	X	X
Fuel combustion						X	
Vehicle wear	X			X	X		
Industrial and household chemicals	X	X		X	X	X	X
Industrial processes	X	X		X	X	X	X
Paints and preservatives					X	X	X
Pesticides				X	X	X	X
Stormwater facilities w/o proper maintenance[1]	X	X	X	X	X	X	X

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Table 1-2. Event Mean Concentrations (mg/L) of Constituents in Denver Metropolitan Area Runoff

(per DRURP and Phase I Stormwater CDPS Permit Application for Denver, Lakewood and Aurora)
(Source: Aurora et al. 1992. *Stormwater NPDES Part 2 Permit Application Joint Appendix* and DRCOG 1983. *Urban Runoff Quality in the Denver Region.*

Constituent	Natural Grassland	Commercial	Residential	Industrial
Total Phosphorus (TP)	0.40	0.42	0.65	0.43
Dissolved or Orthophosphorus (PO_4)	0.10	0.15	0.22	0.2
Total Nitrogen (TN)	3.4	3.3	3.4	2.7
Total Kjeldahl Nitrogen (TKN)	2.9	2.3	2.7	1.8
Ammonia Nitrogen (NH_3)	0.1	1.5	0.7	1.2
Nitrate + Nitrite Nitrogen (NO_3/NO_2)	0.50	0.96	0.65	0.91
Lead (Total Recoverable) (Pb)	0.100	0.059	0.053	0.130
Zinc (Total Recoverable) (Zn)	0.10	0.24	0.18	0.52
Copper (Total Recoverable) (Cu)	0.040	0.043	0.029	0.084
Cadmium (Total Recoverable) (Cd)	Not Detected	0.001	Not Detected	0.003
Chemical Oxygen Demand (COD)	72	173	95	232
Total Organic Carbon (TOC)	26	40	72	22-26
Total Suspended Solids (TSS)	400	225	240	399
Total Dissolved Solids (TDS)	678	129	119	58
Biochemical Oxygen Demand (BOD)	4	33	17	29

3.0 Stormwater Permit Regulations

3.1 Clean Water Act Basics

The Federal Water Pollution Control Act of 1972, as amended (33 U.S.C. 1251 et seq.) is commonly known as the Clean Water Act and establishes minimum stormwater management requirements for urbanized areas in the United States. At the federal level, the EPA is responsible for administering and enforcing the requirements of the Clean Water Act. Section 402(p) of the Clean Water Act requires urban and industrial stormwater be controlled through the NPDES permit program. Requirements affect both construction and post-construction phases of development. As a result, urban areas must meet requirements of Municipal Separate Storm Sewer System (MS4) permits, and many industries and institutions such as state departments of transportation must also meet NPDES stormwater permit requirements. MS4 permittees are required to develop a Stormwater Management Program that includes measurable goals and to implement needed stormwater management controls (i.e., BMPs). MS4 permittees are also required to assess controls and the effectiveness of their stormwater programs and to reduce the discharge of pollutants to the "maximum extent practicable (MEP)." Although it is not the case for every state, the EPA has delegated Clean Water Act authority to the State of Colorado. The State must meet the minimum requirements of the federal program.

3.2 Colorado's Stormwater Permitting Program

The Colorado Water Quality Control Act (25-8-101 et seq., CRS 1973, as amended) established the Colorado Water Quality Control Commission (CWQCC) within the Colorado Department of Public Health and Environment (CDPHE) to develop water quality regulations and standards, classifications of state waters for designated uses, and water quality control regulations. The Act also established the Colorado Water Quality Control Division (CWQCD) to administer and enforce the Act and administer the discharge permit system, among other responsibilities. Violations of the Act are subject to significant monetary penalties, as well as criminal prosecution in some cases.

Colorado's stormwater management regulations have been implemented in two phases and are included in *Regulation No. 61 Colorado Discharge Permit System (CDPS) Regulations* (CWQCC 2009). After the 1990 EPA "Phase I" stormwater regulation became effective, Colorado was required to develop a stormwater program that covered specific types of industries and storm sewer systems for municipalities with populations of more than 100,000. Phase I affected the City of Colorado Springs, Denver, Aurora, Lakewood, and the Colorado Department of Transportation (CDOT). Phase 1 requirements included inventory of stormwater outfalls, monitoring and development of municipal stormwater management requirements, as well as other requirements. Construction activities disturbing five or more acres of land were required to obtain construction stormwater discharge permits.

Phase II of Colorado's stormwater program was finalized in March 2001, establishing additional stormwater permitting requirements. Two major changes included regulation of small municipalities (≥ 10,000 and <100,000 population) in urbanized areas and requiring construction permits for sites disturbing one acre or more. The Phase II regulation resulted in a large number of new permit holders including MS4 permits for El Paso County, City of Fountain, Town of Monument, and City of Manitou Springs. In addition, there are also non-standard MS4 permittees that include entities that are not cities or counties. Non-standard MS4 permittees include entities such as Academy School District 20, Widefield School District 3, Pikes Peak Community College, Harrison School District 2, Falcon School District 49, Cheyenne Mountain School District 12, University of Colorado at Colorado Springs, and Colorado Springs School District 11. MS4 permit holders are required to develop, implement, and enforce a CDPS Stormwater Management Program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable, to protect water quality, and to satisfy the appropriate water quality requirements of the Colorado Water Quality Control Act (25-8-101 et seq., C.R.S.) and the Colorado Discharge Permit Regulations (Regulation 61). Non-standard MS4 permittees may elect to comply with their construction program and post-construction program requirements by following the requirements of the City's or County's construction and post-construction programs.

3.3 City of Colorado Springs MS4 Permit

Stormwater quality protection is authorized by City Code Chapter 3, Article 8 – Storm Water Quality Management and Discharge Control Code. The City's MS4 permit is coordinated by the City's Engineering Division. The MS4 permit requires that they develop and implement certain programs. There are six programs within the MS4 permit and each program has specific tasks that must be achieved or completed within a given time period. The six programs include the following:

1. Commercial/Residential Management Program
2. Illicit Discharges Management Program
3. Industrial Facilities Program
4. Construction Sites Program
5. Pollution Prevention/Good Housekeeping for Municipal Operations
6. Monitoring Program

As a permittee, the City was required to develop, implement, and enforce a pollutant control program to reduce pollutants in stormwater runoff to their MS4 from construction activities that result in land disturbance of one or more acres, including projects less than one acre that are part of a larger common plan of development or sale, as well as address post-construction runoff. Under the post-construction stormwater management in new development and redevelopment provisions, the MS4 permit requires the permittee to develop, implement, and enforce a program to address stormwater runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge into the MS4. The program must ensure controls are in place that would prevent or minimize water quality impacts.

Although MS4 general permits have historically focused on water quality, it is noteworthy that there has been increased emphasis on reducing stormwater runoff through use of Low Impact Development (LID) techniques. The City's MS4 permit language includes the following:

> *Implement and document strategies which include the use of structural and/or non-structural BMPs appropriate for the community, that address the discharge of pollutants from projects, or that follow principles of low-impact development to mimic natural (i.e., pre-development) hydrologic conditions at sites to minimize the discharge of pollutants and prevent or minimize adverse in-channel impacts. associated with increased imperviousness.*

Similarly, at the national level, the Energy Independence and Security Act of 2007 (Pub.L. 110-140) includes Section 438, Storm Water Runoff Requirements for Federal Development Projects. This section requires:

> …any sponsor of any development or redevelopment project involving a federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the

predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

The minimum measures required for development projects to satisfy the City's MS4 permit requirements are described in Section 4.1 of this chapter.

3.4 Total Maximum Daily Loads and Stormwater Management

Section 303(d) of the Clean Water Act requires states to develop a list of water bodies that are not attaining water quality standards for their designated uses, and to identify relative priorities for addressing the impaired water bodies. States must then develop Total Maximum Daily Loads (TMDLs) to assign allowable pollutant loads to various sources to enable the water body to meet the designated uses established for that water body. Implementation plans to achieve the loads specified under TMDLs commonly rely on BMPs to reduce pollutant loads associated with stormwater sources.

In the context of this manual, it is important for designers, planners and other stormwater professionals to understand TMDLs because TMDL provisions can directly affect stormwater permit requirements and BMP selection and design. EPA provides this basic description of TMDLs:

> A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. Pollutant sources are characterized as either regulated stormwater, sometimes called "point sources" that receive a waste load allocation (WLA), or nonpoint sources that receive a load allocation (LA). Point sources include all sources subject to regulation under the NPDES program (e.g., wastewater treatment facilities, most municipal stormwater discharges and concentrated animal feeding operations). Nonpoint sources include all remaining sources of the pollutant, as well as anthropogenic and natural background sources. TMDLs must also account for seasonal variations in water quality, and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.

The TMDL calculation is:

$$\mathrm{TMDL} = \Sigma \mathrm{WLA} + \Sigma \mathrm{LA} + \mathrm{MOS} \qquad \text{Equation 1-1}$$

Where:

ΣWLA = the sum of waste load allocations (point sources),

ΣLA = the sum of load allocations (nonpoint sources and background)

MOS = the margin of safety.

Although states are primarily responsible for developing TMDLs, EPA is required to review and approve or disapprove TMDLs. EPA has developed a basic "TMDL Review Checklist" with the minimum recommended elements that should be present in a TMDL document.

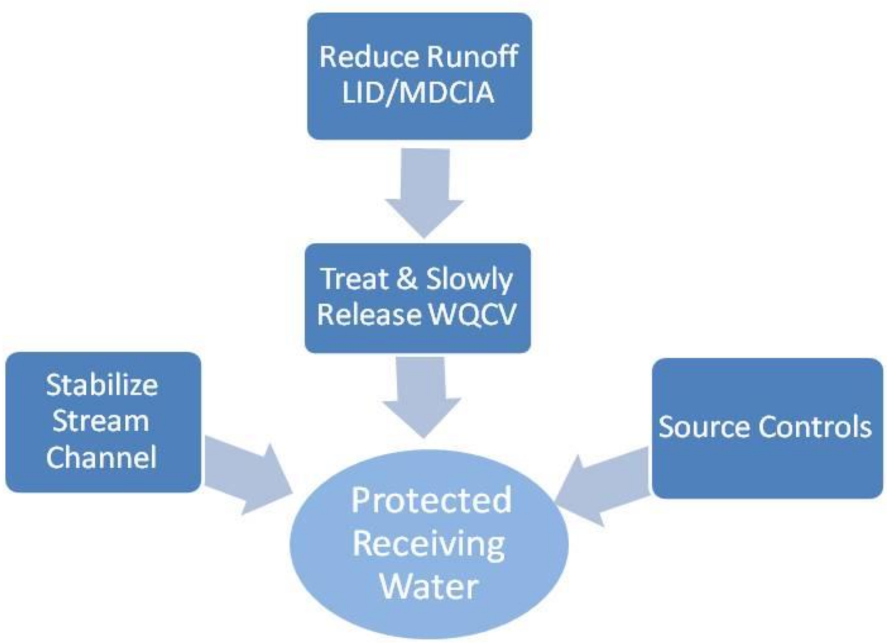
Once EPA approves a TMDL, there are varying degrees of impact to communities involved in the process, generally differentiated among whether point sources or non-point sources of pollution are identified in the TMDL. Permitted stormwater discharges are considered point sources. Essentially, this means that wastewater or stormwater permit requirements consistent with waste load allocations must be implemented and are enforceable under the Clean Water Act through NPDES permits.

If the MS4 permittee discharges into a waterbody with an approved TMDL that includes a pollutant-specific waste load allocation under the TMDL, then the CWQCD can amend the permit to include specific requirements related to that TMDL. For example, the permit may be amended to require specific BMPs, and compliance schedules to implement the BMPs may be required. Numeric effluent limits may also be incorporated under these provisions. TMDLs can have substantive effects on MS4 permit requirements. As an example, the City and County of Denver's MS4 permit has additional requirements to control *E. coli* related to the *E. coli* TMDL approved for the South Platte River (Segment 14). Most stream segments in Colorado Springs are currently listed as impaired for *E. coli*. Information on 303(d) listings and priorities for TMDL development can be obtained from the EPA and CWQCC websites.

4.0 Four Step Process to Minimize Adverse Impacts of Urbanization

Since 2002 with the inception of the DCM, Volume 2, the City of Colorado Springs has required the UDFCD Four Step Process for receiving water protection that focuses on reducing runoff volumes, treating the water quality capture volume (WQCV), stabilizing drainageways, and implementing long-term source controls. The Four Step Process pertains to management of smaller, frequently occurring storm events, as opposed to larger storms for which drainage and flood control infrastructure are sized. Implementation of these four steps helps to achieve stormwater permit requirements. Added benefits of implementing the complete process can include improved site aesthetics through functional landscaping features that also provide water quality benefits. Additionally, runoff reduction can decrease required storage volumes, thus increasing developable land. The Four Step Process, as illustrated and described in the following, is applicable to all new and re-development projects with construction activities that disturb 1 acre or greater or that disturb less than 1 acre but are part of a larger common plan of development or sale. An overview of the Four Step Process follows.

Figure 1-1. The Four Step Process for Stormwater Quality ManagementStep 1.



Employ Runoff Reduction Practices

All land development and re-development activities that disturb 1 acre or more of property either individually or in aggregate, are required to reduce runoff peaks, volumes, and pollutant loads from urbanizing areas, and to implement LID strategies, including MDCIA. For every site, including those smaller than 1 acre but part of a larger common plan of development or sale, look for opportunities to route runoff through vegetated areas, where possible by sheet flow. LID practices reduce unnecessary impervious areas and route runoff from impervious surfaces over permeable areas to slow runoff (increase time of concentration) and promote infiltration. When LID/MDCIA techniques are implemented throughout a development, the effective imperviousness is reduced, thereby potentially reducing sizing requirements for downstream facilities.

Key LID techniques include:

- **Conserve Existing Features**: During the planning phase of development, identify portions of the site that add value and should be protected or improved. Such areas may include mature trees, stream corridors, wetlands, and NRCS Type A/B soils with higher infiltration rates. In order for this step to provide meaningful benefits over the long-term, natural areas must be protected from compaction during constructionthrough the use of temporary construction fence or equivalent. In areas where disturbance cannot practically be avoided, rototilling and soil amendments should be integrated to restore the infiltration capacity of areas that will be restored with vegetation. Revegetation requirements and additional guidance on site preparation is found in the DCM, Volume 2, Chapter 14 (Revegetation).
- **Minimize Impacts**: Consider how the site lends itself to the desired development. In some cases, creative site layout can reduce the extent of paved areas, thereby saving on initial capital cost of pavement and then saving on pavement maintenance, repair, and replacement over time. Minimize imperviousness, including constructing streets, driveways, sidewalks and parking lot aisles to the minimum widths necessary, while still providing for parking, snow management, public safety and fire access. When soils vary over the site, concentrate new impervious areas over NRCS Type C and D soils, while preserving NRCS Type A and B soils for landscape areas and other permeable surfaces. Maintaining natural drainage patterns, implementing sheet flow (as opposed to concentrated flow), and increasing the number and lengths of flow paths will all reduce the impact of the development.

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Differences between LID and Conventional Stormwater Quality Management

Low Impact Development (LID) is a comprehensive land planning and engineering design approach to managing stormwater runoff with a goal of replicating the pre-development hydrologic regime of urban and developing watersheds. Given the increased regulatory emphasis on LID, runoff reduction and mimicking pre-development hydrology, questions may arise related to the differences between conventional stormwater management and LID. For example, Volume 2 has emphasized MDCIA as the first step in stormwater quality planning and has provided guidance on LID techniques such as grass swales, grass buffers, permeable pavement systems, bioretention, and pollution prevention (pollutant source controls). Although these practices are all key components of LID, LID is not limited to a set of practices targeted at promoting infiltration. Key components of LID, in addition to individual BMPs, include practices such as:

- An overall site planning approach that promotes conservation design at both the watershed and site levels. This approach to development seeks to "fit" a proposed development to the site, integrating the development with natural features and protecting the site's natural resources. This includes practices such as preservation of natural areas including open space, wetlands, soils with high infiltration potential, and stream buffers. Minimizing unnecessary site disturbances (e.g., grading, compaction) is also emphasized.

- A site design philosophy that emphasizes multiple controls distributed throughout a development, as opposed to a central treatment facility.

- The use of swales and open vegetated conveyances, as opposed to curb and gutter systems.

- Volume reduction as a key hydrologic objective, as opposed to peak flow reduction being the primary hydrologic objective. Volume reduction is emphasized not only to reduce pollutant loading and peak flows, but also to move toward hydrologic regimes with flow durations and frequencies closer to the natural hydrologic regime.

Even with LID practices in place, most sites will also require centralized flood control facilities. In some cases, site constraints may limit the extent to which LID techniques can be implemented, whereas in other cases, developers and engineers may have significant opportunities to integrate LID techniques that may be overlooked due to the routine nature and familiarity of conventional approaches. This manual provides design criteria and guidance for both LID and conventional stormwater quality management, and provides additional facility sizing credits for implementing Step 1, Runoff Reduction, in a more robust manner.

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Permeable pavement techniques and green roofs are common LID practices that enhance infiltration and reduce the impacts of paved areas and roofs:

- **Permeable Pavement**: The use of various permeable pavement techniques as alternatives to paved areas can significantly reduce site imperviousness.

- **Green Roofs**: Green roofs can be used to decrease imperviousness associated with buildings and structures. Benefits of green roofs vary based on design of the roof. Research is underway to assess the effectiveness of green roofs in Colorado's semi-arid climate.

- **Minimize Directly Connected Impervious Areas (MDCIA)**: Impervious areas should drain to pervious areas. Use non-hardened drainage conveyances where appropriate. Route downspouts across pervious areas, and incorporate vegetation in areas that generate and convey runoff. Three key BMPs include:

  - **Grass Buffers**: Sheet flow over a grass buffer slows runoff, encourages infiltration, and enhances sediment removal, reducing effects of the impervious area.

  - **Grass Swales**: Like grass buffers, use of grass swales instead of hardened channels or storm sewers slows runoff and promotes infiltration, also reducing the effects of imperviousness.

  - **Bioretention (rain gardens)**: The use of distributed on-site vegetated features such as rain gardens can help maintain natural drainage patterns by allowing more infiltration onsite. Bioretention can also treat the WQCV, as described in the Four Step Process.

Historically, this critical volume reduction step has been overlooked by planners and engineers, despite WQCV reductions allowed based on MDCIA. In addition to benefiting the environment through reduced hydrologic and water quality impacts, volume reduction measures can also have the added economic benefit to the developer of increasing the area of developable land by reducing required detention volumes and potentially reducing both capital and maintenance costs.

Photograph 1-1. **Permeable Pavement**. Permeable pavement consists of a permeable pavement layer underlain by gravel and sand layers in most cases. Uses include parking lots and low traffic areas, to accommodate vehicles while facilitating stormwater infiltration near its source. Photo courtesy of Bill Wenk.

Photograph 1-2. Grass Buffer. This roadway provides sheet flow to a grass buffer. The grass buffer provides filtration, infiltration, and settling to reduce runoff pollutants.

Photograph 1-3. Grass Swale. This densely vegetated drainageway is designed with channel geometry that forces the flow to be slow and shallow, facilitating sedimentation while limiting erosion.

Step 2. Implement BMPs That Provide a Water Quality Capture Volume with Slow Release

After runoff reduction through Step 1, the remaining runoff must be treated through capture and slow release of the WQCV. WQCV facilities may provide both water quality and volume reduction benefits, depending on the BMP selected. This manual provides design guidance for BMPs providing treatment of the WQCV, including permeable pavement systems with subsurface storage, bioretention, extended detention basins, sand filters, and constructed wetland ponds. Chapter 3 provides background information on the development of the WQCV as well as a step-by-step procedure to calculate the WQCV.

Practical Tips for Runoff Reduction and Better Integration of Water Quality Facilities
(Adapted from: Denver Water Quality Management Plan, WWE et al. 2004)

- **Consider stormwater quality needs early in the development process.** When left to the end of the site development process, stormwater quality facilities will often be shoe-horned into the site, resulting in few options. When included in the initial planning for a project, opportunities to integrate stormwater quality facilities into a site can be fully realized. Dealing with stormwater quality after major site plan decisions have been made is too late and often makes implementation of LID designs impractical.

- **Take advantage of the entire site when planning for stormwater quality treatment.** Stormwater quality and flood detention is often dealt with only at the low corner of the site, and ignored on the remainder of the site. The focus is on draining runoff quickly through inlets and storm sewers to the detention facility. In this "end-of-pipe" approach, all the runoff volume is concentrated at one point and designers often find it difficult to fit the required detention into the space provided. Treating runoff over a larger portion of the site reduces the need for big corner basins and allows implementation of LID principles.

- **Place stormwater in contact with the landscape and soil**. Avoid routing storm runoff from pavement to inlets to storm sewers to offsite pipes or concrete channels. The recommended approach places runoff in contact with landscape areas to slow down the stormwater and promote infiltration. Permeable pavement areas also serve to reduce runoff and encourage infiltration.

- **Minimize unnecessary imperviousness, while maintaining functionality and safety.** Smaller street sections or permeable pavement in fire access lanes, parking lanes, overflow parking, and driveways will reduce the total site imperviousness.

- **Select treatment areas that promote greater infiltration.** Bioretention, permeable pavements, and sand filters promote greater volume reduction than extended detention basins, because runoff tends to be absorbed into the filter media or infiltrate into underlying soils. As such, they are more efficient at reducing runoff volume and can be sized for smaller treatment volumes than extended detention basins.

Step 3. Stabilize Drainageways

During and following development, natural drainageways are often subject to bed and bank erosion resulting from increases in frequency, duration, rate, and volume of runoff. Although Steps 1 and 2 help to minimize these effects, drainageway stabilization that protects the bed and bank of the channel from these increases in runoff is required. Many drainageways are included in basin master plans or major drainageway plans that identify needed channel stabilization measures to accommodate developed flows. These measures not only protect infrastructure such as utilities, roads and trails, but are also important to control sediment loading from erosion of the channel itself, which can be a significant source of sediment and associated constituents, such as phosphorus, metals and other naturally occurring constituents. If stream stabilization is implemented early in the development process, it is far more likely that natural drainageway characteristics can be maintained with the addition of grade control to accommodate future development. Targeted fortification of a relatively stable drainageway is typically much less costly than repairing a degraded channel. The Drainage Criteria Manual, Volume 1 provides requirements for channel stabilization, including stabilized natural channels and several engineered channel approaches. This manual also describes a Constructed Wetland Channel approach, which may provide additional water quality and community benefits. Brief descriptions of these three approaches to stabilized channels include:

- **Stabilized Natural Channel**. Natural drainageways in and adjacent to new developments usually receive increased low flows due to urbanization even when upstream detention storage is provided. Urban development causes channels to become destabilized disturbing riparian vegetation and habitat and transporting sediment downstream. Therefore, some level of stream stabilization is always necessary. Small grade control structures sized for low flows are often an effective means of establishing a mild slope for the main channel and arresting stream degradation. Severe bends or cut banks may also need to be stabilized. When site conditions are suitable Constructed Wetland Channels can be implemented. Wetland bottoms use dense natural vegetation to slow runoff and promote settling and biological uptake. These are particularly beneficial in treatment train approaches where pre-sedimentation occurs upstream of the wetland channel. Such efforts to stabilize a natural waterway enhance aesthetics, riparian and stream habitat, and water quality. Drainageway design should always be completed in accordance with master planning documents when available.

- **Constructed Natural Channel**. When upstream flood flows increase so that channel capacity improvements are needed and sufficient right-of-way is available, constructed natural channels can provide benefits similar to natural channels. These channels provide water quality benefits through infiltration and pollutant uptake through vegetation. Grade control structures in these channels also reduce velocities and prevent bed and bank erosion.

- **Engineered Channel**: Engineered channels may be necessary when the upstream basin has developed without detention storage or when adjacent properties are subject to flooding or erosion. These channels are typically lined with rip-rap or cobblestone and do not enhance infiltration or water quality beyond the reduction of bed and bank erosion.

All new and re-development projects are required to construct or participate in the funding of the construction of the channel stabilization measures required by the applicable DBPS or master plan or needed to ensure channel stability. Developers shall be required to show that DBPS recommendations for stabilized or constructed natural channels are not feasible before engineered channels are proposed.

Step 4. Implement Site Specific and Other Source Control BMPs

Site specific needs such as material storage or other site operations require targeted source control BMPs. This is often the case for new development or significant redevelopment of an industrial or commercial site. Chapter 5 includes information on source control practices such as covering storage/handling areas and spill containment and control. All new and re-development that includes outdoor storage or the potential for the introduction of contaminants to the City's MS4 shall be required to implement site specific and/or source control BMPs to protect receiving waters.

4.1 City of Colorado Springs MS4 Permit and Implementation of the Four-step Process

5.0 The entire Four-Step Process is required for all land distrurbance activities greater than 1 acre or less than an acre if part of a larger common plan of development or sale. Implementing runoff reduction methods as described in Step 1 is an effective means of providing water quality treatment and must be implemented in order to contribute to the requirements described in Step 2. Source controls described in Step 4 may also be required under permits issued by other agencies. Stormwater BMPs: Onsite, Sub-regional and Regional

Stormwater BMPs are required to be implemented as close to the source as practicable, resulting in smaller BMPs (in parallel or in series) that are distributed throughout a site or subbasin. Whereas flood control is best handled on a regional basis, stormwater quality is best managed when stormwater is viewed as a resource and distributed throughout the site. Although not preferred, WQCV facilities may be implemented regionally (serving a drainageway with a drainage area between 130 acres and 640 acres, one square mile) in accordance with an approved drainage master planning study. Subregional (serving two or more development parcels with a total drainage area less than 130 acres) implementation is preferred, as this strategy protects State Waters in compliance with the City's MS4 permit. Drainage master plans must be consulted to determine if regional or subregional facilities are already planned or in place for new developments or redevelopments.

Whereas flood control is best handled on a regional basis, stormwater quality is best managed as a resource and distributed throughout the site.

Life-cycle costs of onsite, subregional, and regional facilities, including long-term maintenance responsibilities, must also be part of the decision-making process when selecting the combinations of facilities and channel improvements needed to serve a development or redevelopment. Potential benefits of subregional facilities include consolidated maintenance efforts, economies of scale for larger facilities as opposed to multiple onsite WQCV facilities, and potential integration with flood control facilities. In addition, sub-regional storage-based facilities may be beneficial in areas where onsite BMPs are not feasible due to geotechnical or land use constraints or when retrofitting an existing flood control facility in a fully developed watershed.

The most common challenges regarding regional facilities relate to protection of State Waters and the timing of funding for construction of the facilities. Often, regional facilities are funded by revenues collected from new development activities. New developments (and revenues) are required to fund construction of the water quality facility, but the water quality facility is needed upfront to provide protection for new development. This timing problem can be solved by constructing onsite water quality facilities for new development that occur before a regional facility is in place. These onsite BMPs may be temporary in that they can be converted to developable land once the regional facility is constructed.

State Waters

State Waters are any and all surface and subsurface waters which are contained in or flow in or through this State, but does not include waters in sewage systems, waters in treatment works of disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed (from Regulation 61, Colorado Discharge Permit System Regulations).

Regional water quality facilities may be selected if they are planned as part of an approved Drainage Basin Planning Study. BMPs are still required onsite to address water quality and channel stability for the reach of the drainageway upstream of the regional facility. In accordance with MS4 permits and regulations, BMPs must be implemented prior to discharges to a State Water from areas of "New Development and Significant Redevelopment." Therefore, if a regional BMP is utilized downstream of a discharge from a development into a State Water, additional BMPs are required to protect the State Water between the development site and the regional facility. Additional requirements may also apply in the case of streams with TMDLs. As a result, MS4 permit holders must have a program in place that requires developers to provide adequate onsite measures so that the MS4 permit holder remains in compliance with their permit and meets the conditions of current regulations.

When a regional or sub-regional facility is selected to treat the WQCV for a development, the remaining three steps in the Four Step Process must still be implemented. For example, minimizing runoff on the developed property by disconnecting impervious area and infiltrating runoff onsite (Step 1) can potentially reduce regional WQCV requirements, conveyance system costs, and costs of the regional/sub-regional facility. Stream stabilization requirements (Step 3) must still be evaluated and implemented, particularly if identified in a master drainage plan. Finally, specific source controls (Step 4) such as materials coverage should be implemented onsite, even if a regional/sub-regional facility is provided downstream.

Chapter 2 provides a stormwater BMP selection tool to help planners and engineers determine whether onsite or subregional strategies are best suited to the given watershed conditions.

6.0 Conclusion

Urban stormwater runoff can have a variety of chemical, biological, and physical effects on receiving waters. As a result, local governments must comply with federal, state and local requirements to minimize adverse impacts both during and following construction. Runoff mitigation measures are based on a Four Step Process focused on reducing runoff volumes, treating the remaining WQCV, stabilizing receiving drainageways and providing targeted source controls for post-construction operations at a site. Stormwater management requirements and objectives should be considered early in the site development process, taking into account a variety of factors, including the effectiveness of the BMP, long-term maintenance requirements, cost and a variety of site-specific conditions. The remainder of this manual provides requirements for selecting, designing, constructing and maintaining stormwater BMPs.

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